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(54) **SYSTEM AND METHOD FOR EXCHANGING INFORMATION IN A MOBILE WIRELESS NETWORK ENVIRONMENT**

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See application file for complete search history.

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(57) **ABSTRACT**

A method is provided in one example embodiment and includes communicating a message from a network element to a remote data plane element in order to request a data plane resource for hosting a session for a particular subscriber. The remote data plane element is designated to host a data plane function for a particular mobile network subscriber and the data plane resource comprises at least one of memory space and processor allocation. The method further includes discovering nodes capable of supporting the control plane functions; discovering nodes capable of supporting the data plane functions for the session; and performing a
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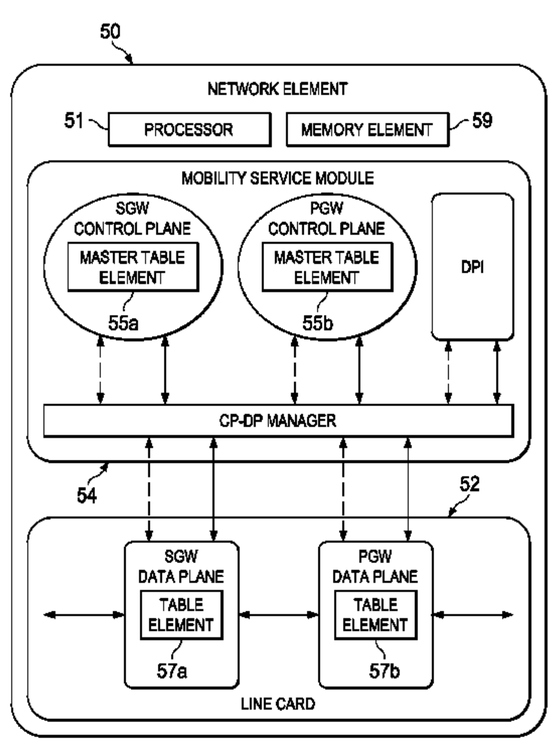

system-specific internal configuration to support separation of the data plane functions and the control plane functions.

20 Claims, 8 Drawing Sheets

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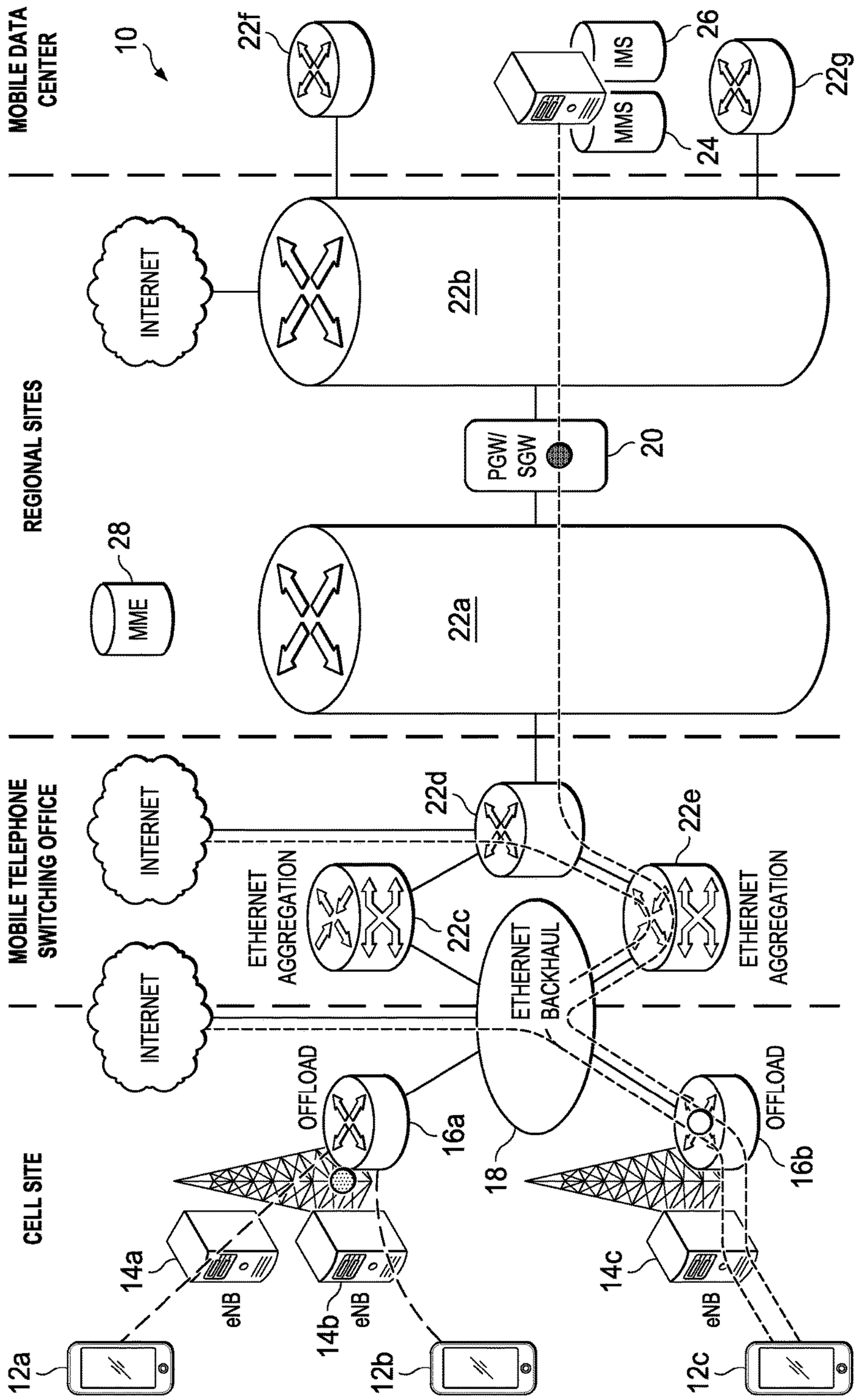
MOBILE DATA CENTER
10
22f
IMS
26
MMS
24
22g
INTERNET
22b
REGIONAL SITES
PGW/ SGW
20
28
MME
22a
MOBILE TELEPHONE SWITCHING OFFICE
INTERNET
22d
22e
ETHERNET AGGREGATION
22c
ETHERNET BACKHAUL
ETHERNET AGGREGATION
INTERNET
OFFLOAD
16a
18
OFFLOAD
16b
CELL SITE
14a
eNB
14b
eNB
14c
eNB
12a
12b
12c

FIG. 1

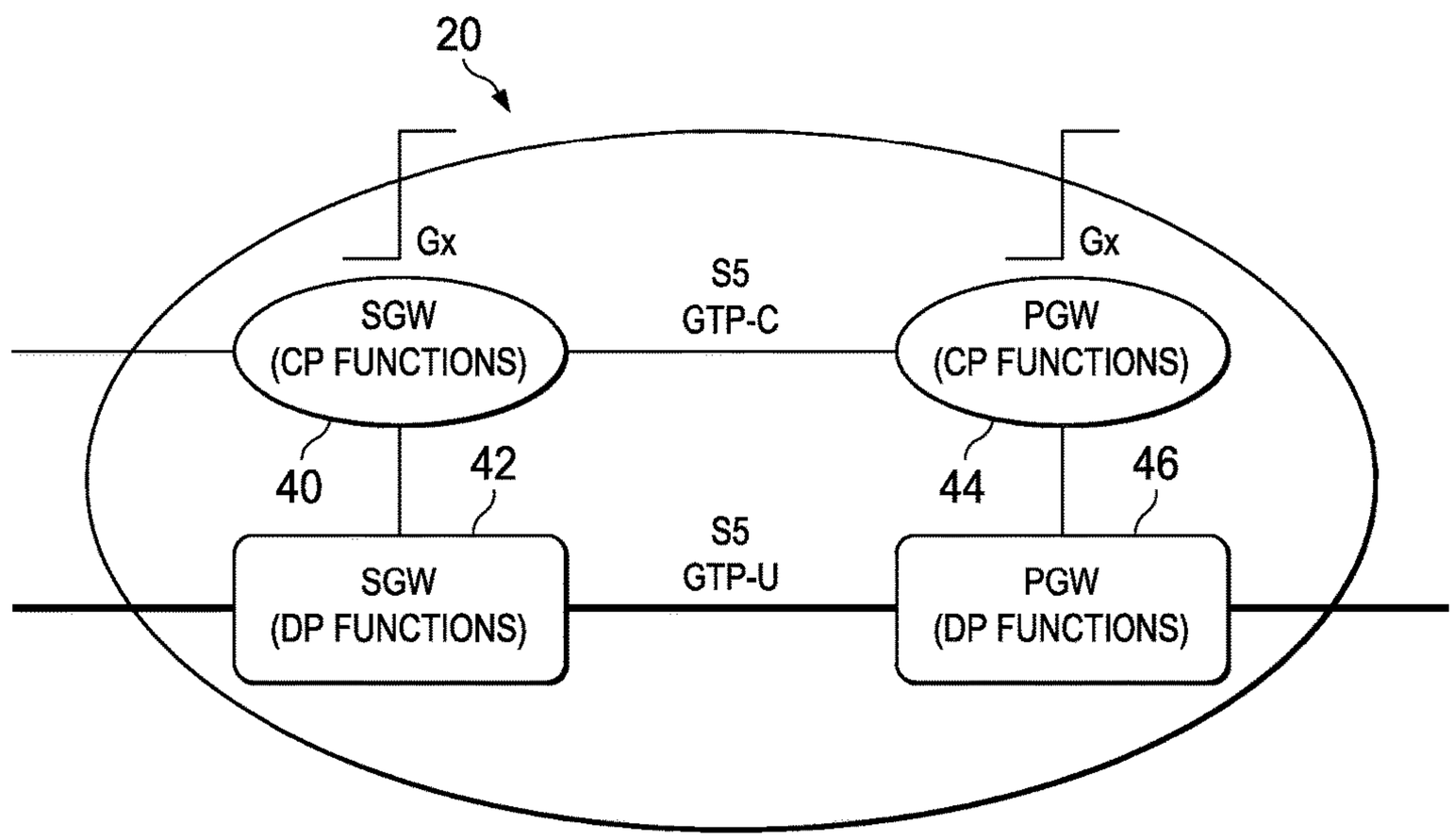
20
Gx
Gx
S5
GTP-C
SGW
(CP FUNCTIONS)
PGW
(CP FUNCTIONS)
40
42
44
46
S5
GTP-U
SGW
(DP FUNCTIONS)
PGW
(DP FUNCTIONS)

FIG. 2

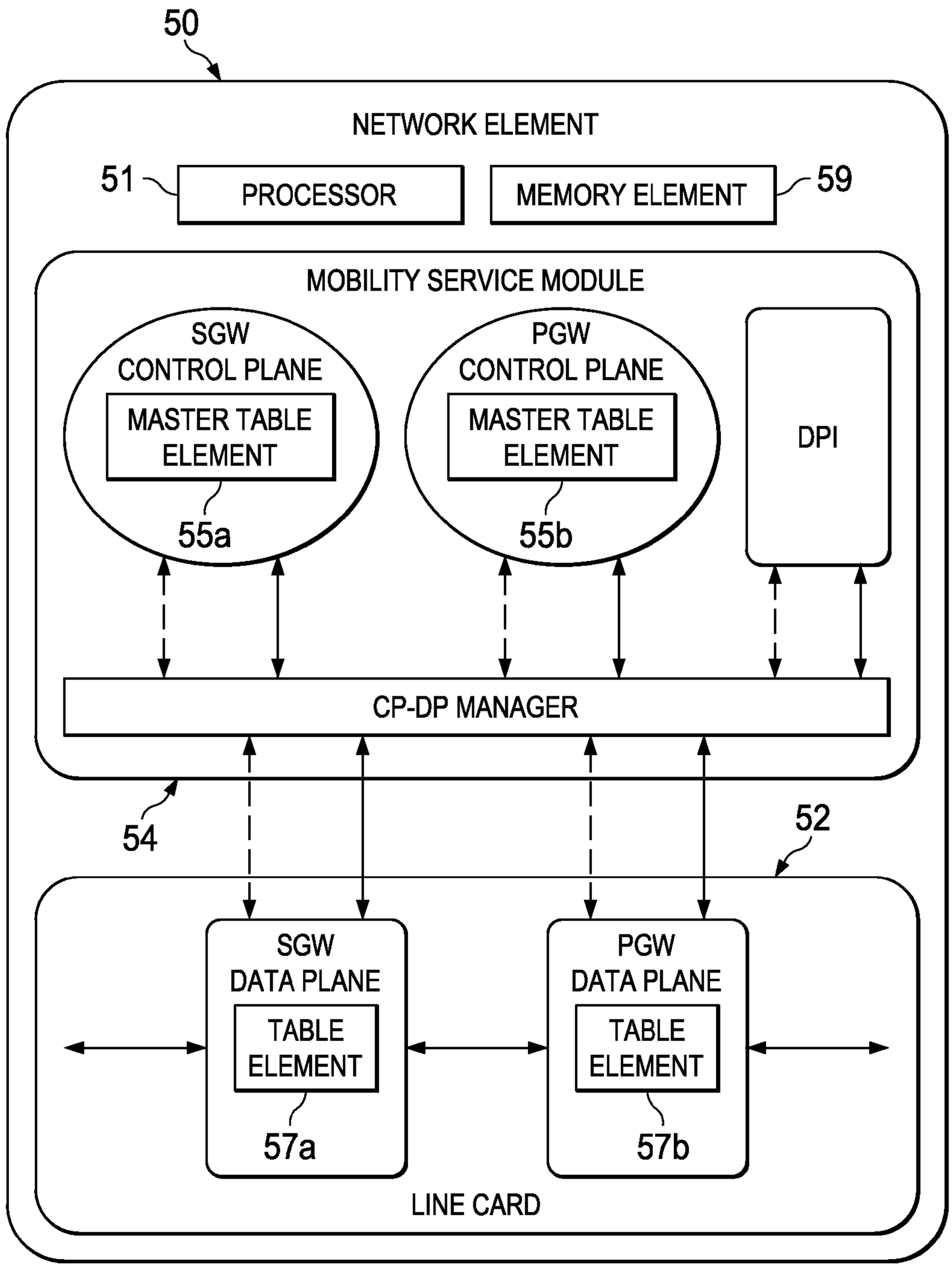
50
NETWORK ELEMENT
51
PROCESSOR
MEMORY ELEMENT
59
MOBILITY SERVICE MODULE
SGW
CONTROL PLANE
MASTER TABLE
ELEMENT
55a
PGW
CONTROL PLANE
MASTER TABLE
ELEMENT
55b
DPI
CP-DP MANAGER
54
52
SGW
DATA PLANE
TABLE
ELEMENT
57a
PGW
DATA PLANE
TABLE
ELEMENT
57b
LINE CARD

FIG. 3

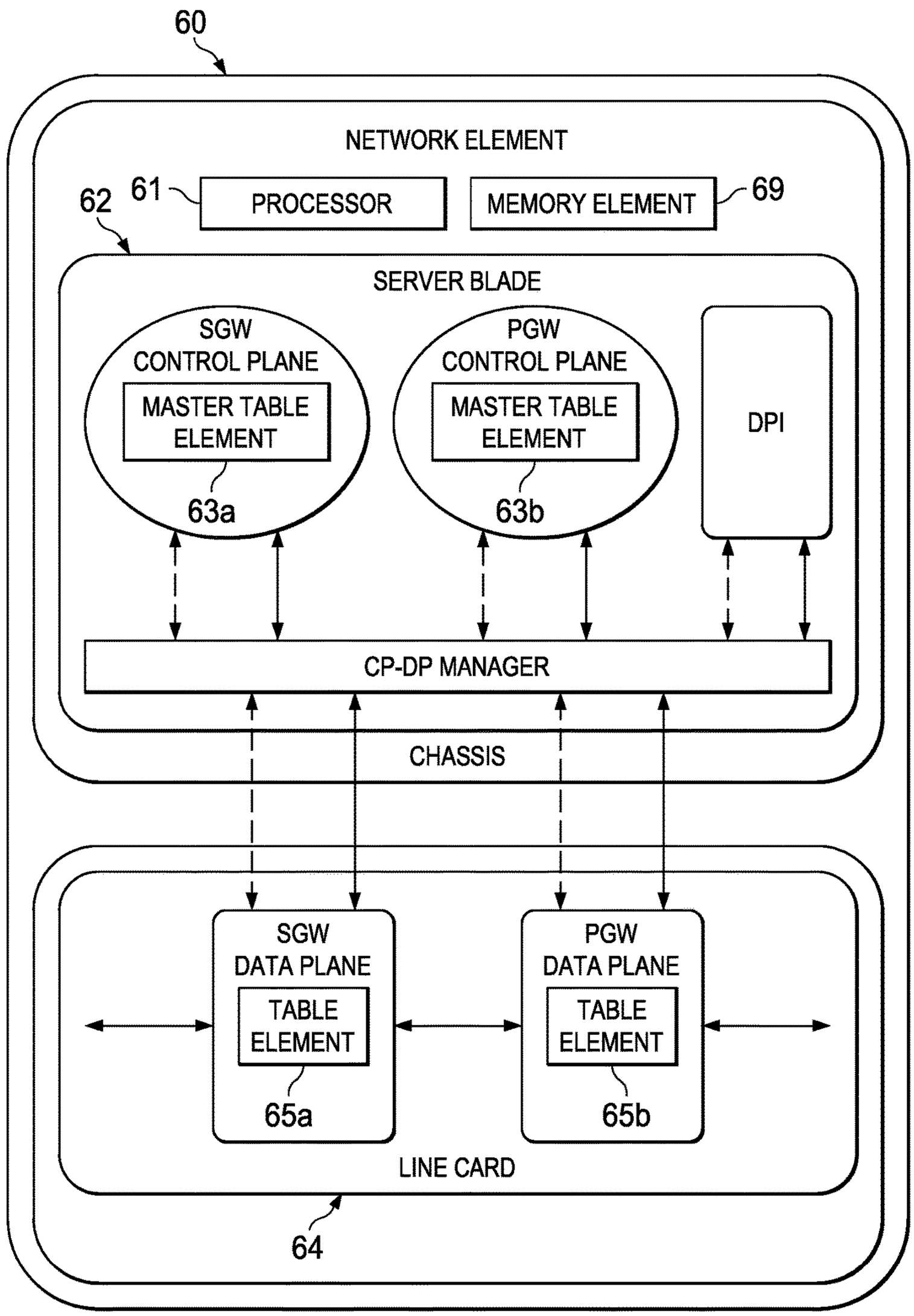
60
NETWORK ELEMENT
62
61
PROCESSOR
MEMORY ELEMENT
69
SERVER BLADE
SGW
CONTROL PLANE
MASTER TABLE
ELEMENT
63a
PGW
CONTROL PLANE
MASTER TABLE
ELEMENT
63b
DPI
CP-DP MANAGER
CHASSIS
SGW
DATA PLANE
TABLE
ELEMENT
65a
PGW
DATA PLANE
TABLE
ELEMENT
65b
LINE CARD
64

FIG. 4

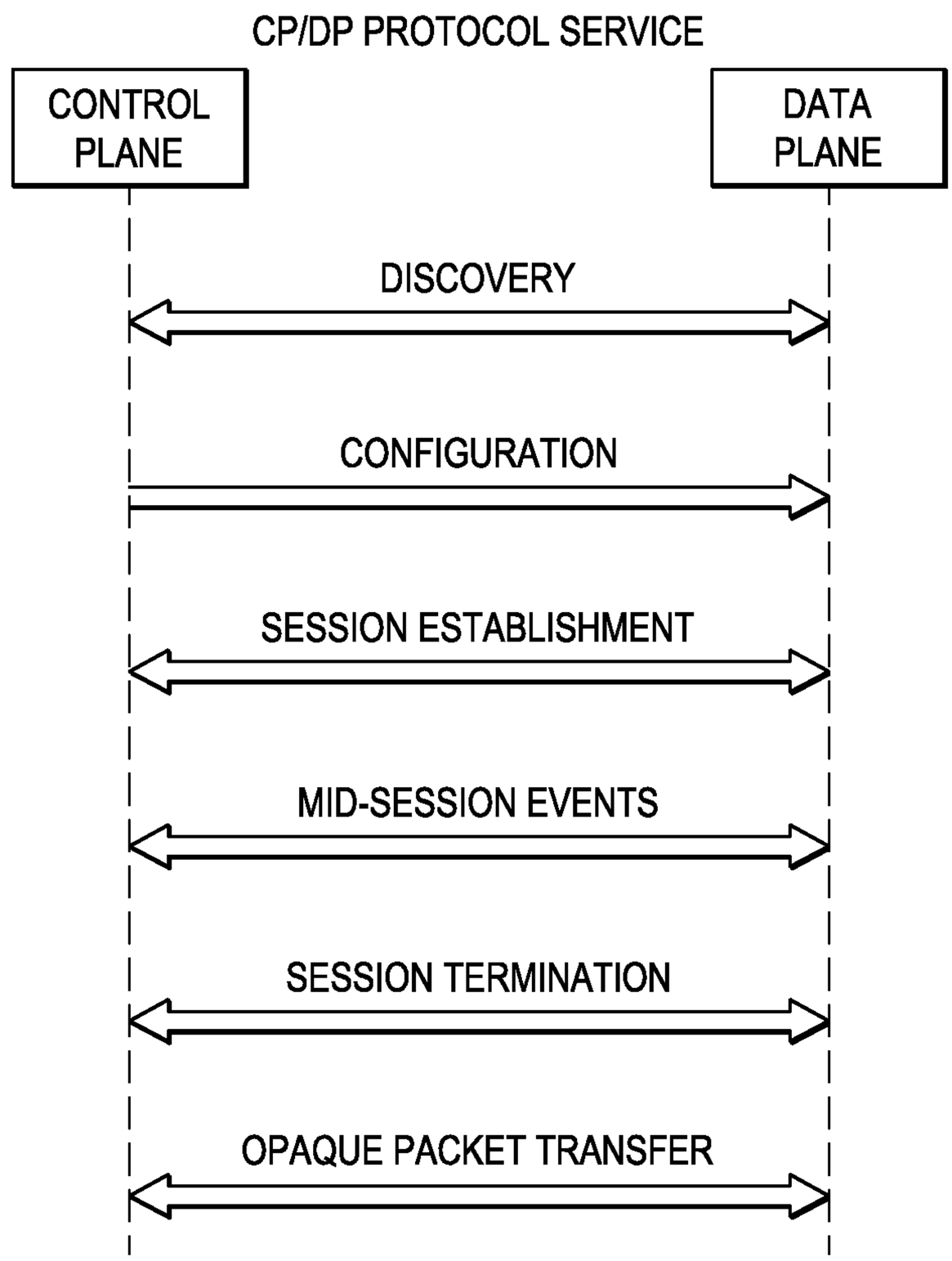
CP/DP PROTOCOL SERVICE
CONTROL PLANE
DATA PLANE
DISCOVERY
CONFIGURATION
SESSION ESTABLISHMENT
MID-SESSION EVENTS
SESSION TERMINATION
OPAQUE PACKET TRANSFER

FIG. 5

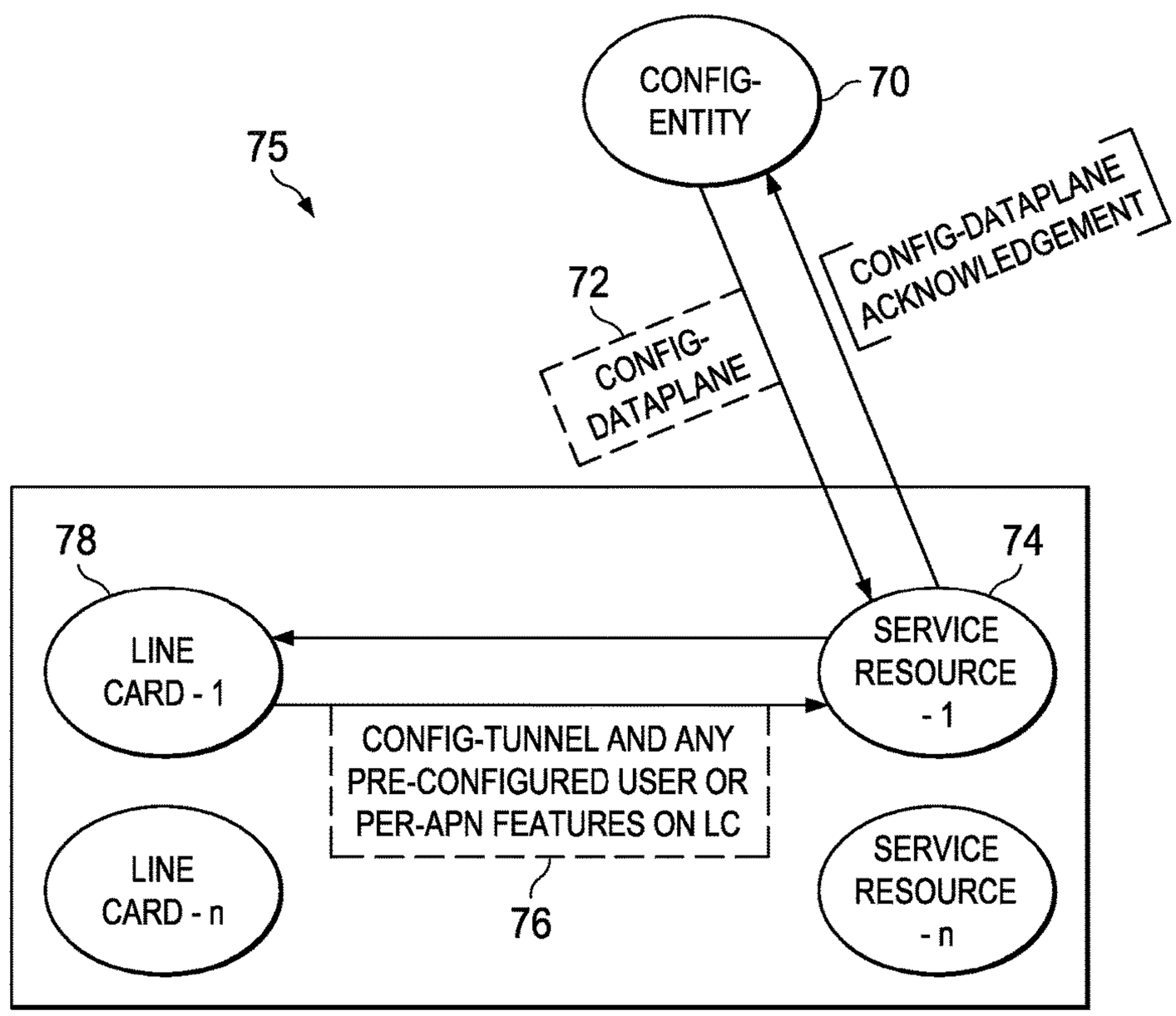
CONFIG-
ENTITY
70
75
CONFIG-DATAPLANE
ACKNOWLEDGEMENT
72
CONFIG-
DATAPLANE
78
74
LINE
CARD - 1
SERVICE
RESOURCE
- 1
CONFIG-TUNNEL AND ANY
PRE-CONFIGURED USER OR
PER-APN FEATURES ON LC
LINE
CARD - n
76
SERVICE
RESOURCE
- n

FIG. 6

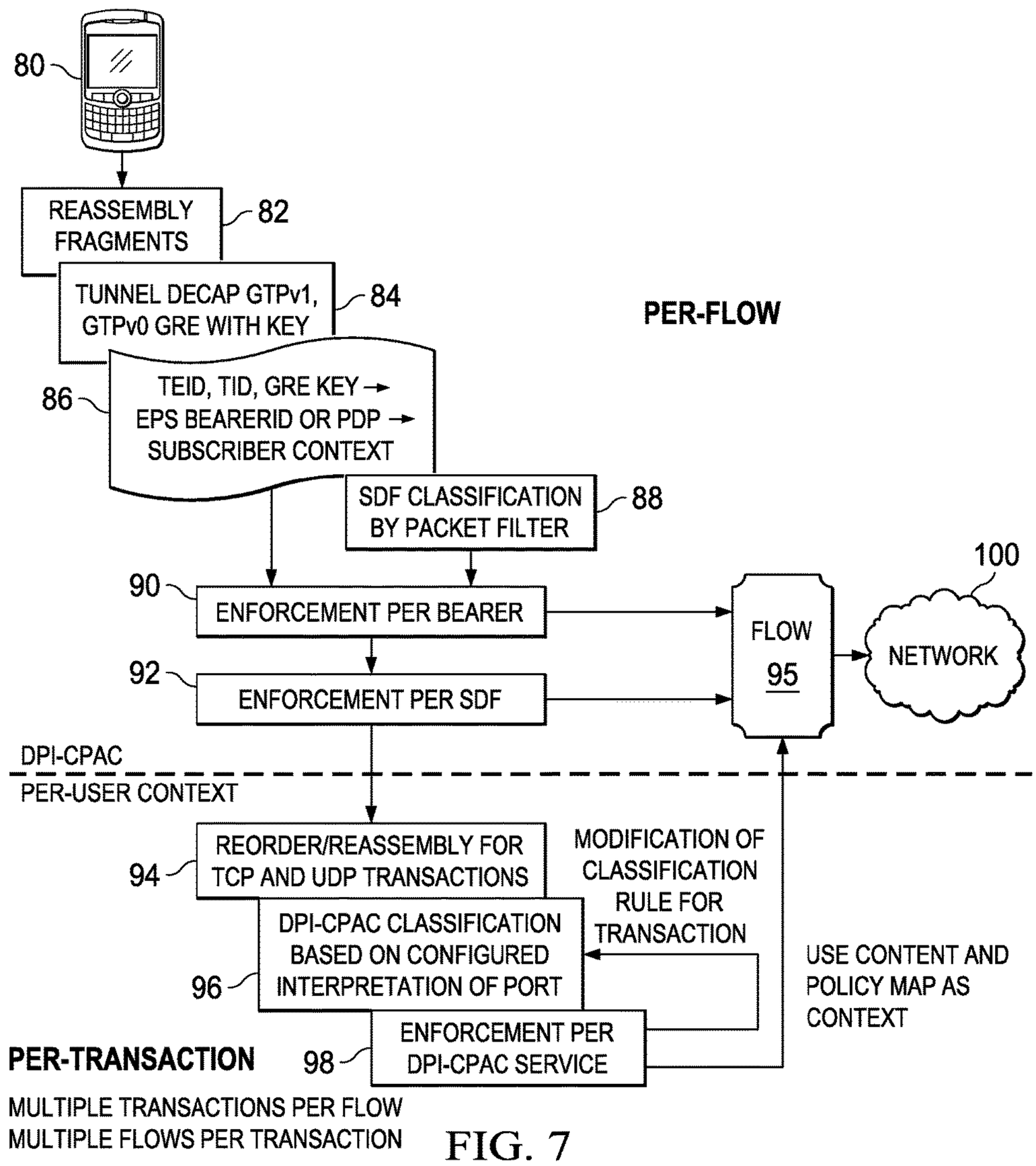
80
REASSEMBLY FRAGMENTS
82
TUNNEL DECAP GTPv1, GTPv0 GRE WITH KEY
84
PER-FLOW
86
TEID, TID, GRE KEY
EPS BEARERID OR PDP
SUBSCRIBER CONTEXT
SDF CLASSIFICATION BY PACKET FILTER
88
100
90
ENFORCEMENT PER BEARER
FLOW
95
NETWORK
92
ENFORCEMENT PER SDF
DPI-CPAC
PER-USER CONTEXT
94
REORDER/REASSEMBLY FOR TCP AND UDP TRANSACTIONS
MODIFICATION OF CLASSIFICATION RULE FOR TRANSACTION
DPI-CPAC CLASSIFICATION BASED ON CONFIGURED INTERPRETATION OF PORT
96
USE CONTENT AND POLICY MAP AS CONTEXT
PER-TRANSACTION
98
ENFORCEMENT PER DPI-CPAC SERVICE
MULTIPLE TRANSACTIONS PER FLOW
MULTIPLE FLOWS PER TRANSACTION

FIG. 7

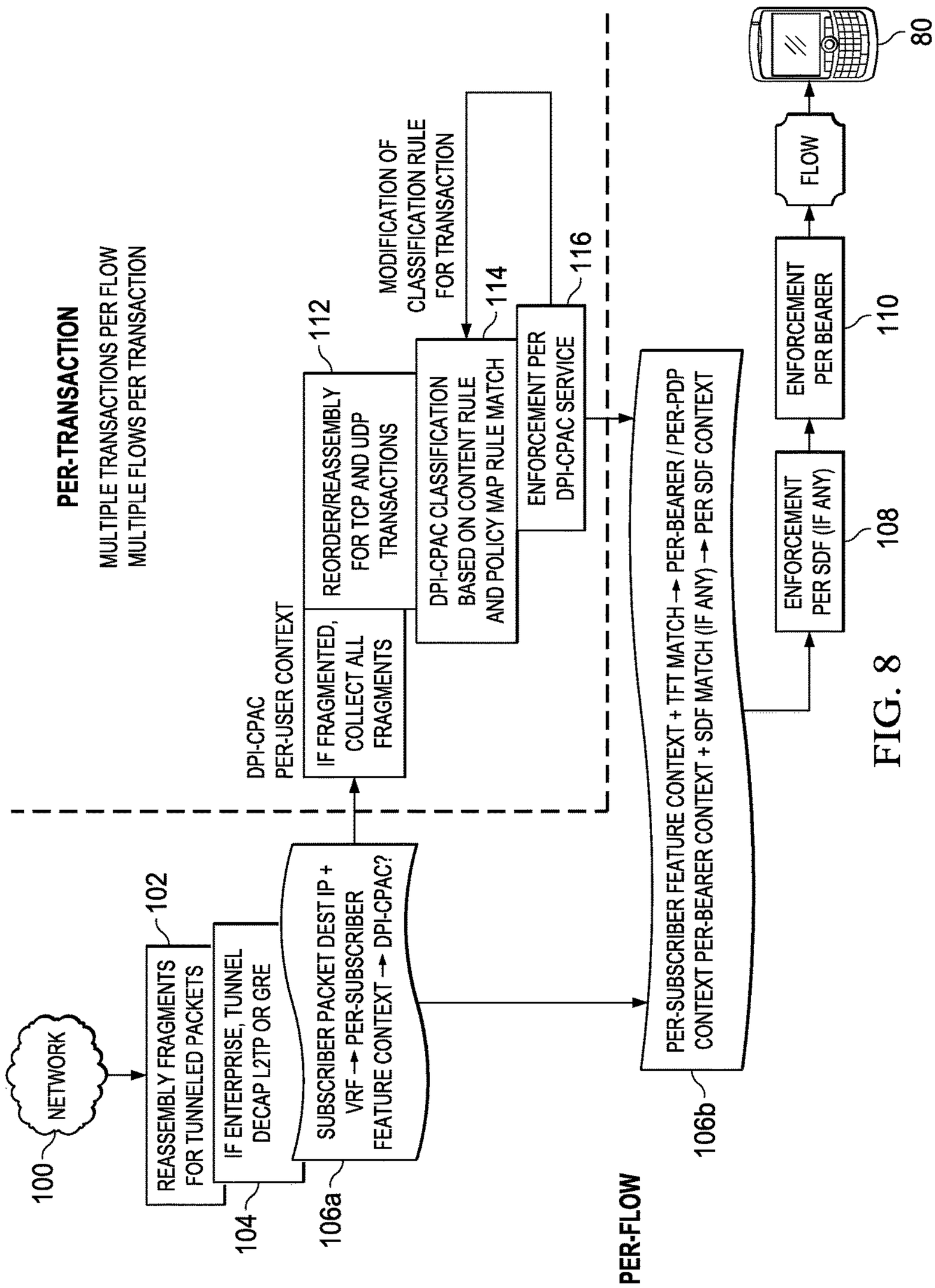
PER-TRANSACTION
MULTIPLE TRANSACTIONS PER FLOW
MULTIPLE FLOWS PER TRANSACTION
NETWORK
100
REASSEMBLY FRAGMENTS FOR TUNNELED PACKETS
102
IF ENTERPRISE, TUNNEL DECAP L2TP OR GRE
104
SUBSCRIBER PACKET DEST IP + VRF → PER-SUBSCRIBER FEATURE CONTEXT → DPI-CPAC?
106a
DPI-CPAC PER-USER CONTEXT
IF FRAGMENTED, COLLECT ALL FRAGMENTS
REORDER/REASSEMBLY FOR TCP AND UDP TRANSACTIONS
112
DPI-CPAC CLASSIFICATION BASED ON CONTENT RULE AND POLICY MAP RULE MATCH
114
MODIFICATION OF CLASSIFICATION RULE FOR TRANSACTION
ENFORCEMENT PER DPI-CPAC SERVICE
116
PER-FLOW
PER-SUBSCRIBER FEATURE CONTEXT + TFT MATCH → PER-BEARER / PER-PDP CONTEXT PER-BEARER CONTEXT + SDF MATCH (IF ANY) → PER SDF CONTEXT
106b
ENFORCEMENT PER SDF (IF ANY)
108
ENFORCEMENT PER BEARER
110
FLOW
80

FIG. 8

SYSTEM AND METHOD FOR EXCHANGING INFORMATION IN A MOBILE WIRELESS NETWORK ENVIRONMENT

RELATED APPLICATION

This Application is a continuation (and claims the benefit of priority under 35 U.S.C. § 120) of U.S. application Ser. No. 12/984,034, filed Jan. 4, 2011, entitled "SYSTEM AND METHOD FOR EXCHANGING INFORMATION IN A MOBILE WIRELESS NETWORK ENVIRONMENT," Inventors Gary B. Mahaffey, et al. The disclosure of the prior application is considered part of (and is incorporated by reference in) the disclosure of this application.

TECHNICAL FIELD

This disclosure relates in general to the field of communications, and more particularly, to exchanging information in a mobile wireless network.

BACKGROUND

Networking architectures have grown increasingly complex in communications environments, particularly mobile wireless environments. Mobile data traffic has grown extensively in recent years; the types of data being transported through mobile wireless networks have also changed dramatically. Video, file-sharing, and other types of usages (more traditionally associated with wired networks) have been gradually displacing voice as the dominant traffic in mobile wireless networks. In addition, the augmentation of clients or end users wishing to communicate in a network environment has caused many networking configurations and systems to respond by adding elements to accommodate the increase in networking traffic. As the subscriber base of end users increases, proper routing and efficient management of communication sessions and data flows become even more critical. Hence, there is a significant challenge in coordinating which flows merit particular processing in order to minimize resources and expenses associated with optimally managing network traffic.

BRIEF DESCRIPTION OF THE DRAWINGS

To provide a more complete understanding of the present disclosure and features and advantages thereof, reference is made to the following description, taken in conjunction with the accompanying figures, wherein like reference numerals represent like parts, in which:

FIG. **1** is a simplified block diagram illustrating a communication system for exchanging information in a mobile wireless network environment according to one embodiment of the present disclosure;

FIG. **2** is a simplified block diagram illustrating logical components of a gateway provided in the mobile wireless network environment according to one example of the present disclosure;

FIG. **3** is a simplified block diagram illustrating an arrangement of a gateway provided in the mobile wireless network environment according to one example of the present disclosure;

FIG. **4** is a simplified block diagram illustrating a gateway in the mobile wireless network environment according to one example of the present disclosure;

FIG. **5** is a simplified flow diagram illustrating potential operations associated with a protocol service according to one example of the present disclosure;

FIG. **6** is a simplified flow diagram illustrating potential operations associated with network elements in the mobile wireless network environment according to one example of the present disclosure;

FIG. **7** is a simplified flow diagram illustrating potential operations associated with processing packets originating from a mobile device in the mobile wireless network according to an example of the present disclosure; and

FIG. **8** is a simplified flow diagram illustrating potential operations associated with processing packets originating in the mobile wireless network according to one example of the present disclosure.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

Overview

A method is provided in one example embodiment and includes communicating a message from a network element to a remote data plane element in order to request a data plane resource for hosting a session for a particular subscriber. The remote data plane element is designated to host a data plane function for a particular mobile network subscriber and the data plane resource comprises at least one of memory space and processor allocation. The method further includes discovering nodes capable of supporting the control plane functions; discovering nodes capable of supporting the data plane functions for the session; and performing a system-specific internal configuration to support separation of the data plane functions and the control plane functions.

Example Embodiments

Turning to FIG. **1**, FIG. **1** is a simplified block diagram of an example embodiment of a communication system **10**, which can be associated with a mobile wireless network. The example architecture of FIG. **1** includes multiple instances of user equipment (UE) **12***a-c*: each of which may connect wirelessly to a respective eNode B (eNB) **14***a-c*. Each eNB **14***a-c* may be connected to a network element **16***a-b*, which can be tasked with providing offload functionalities for the architecture. Network elements **16***a-b* are connected to an Ethernet backhaul **18**. Communication system **10** can also include various network elements **22***a-g*, which can be used to exchange packets in a network environment. As illustrated, the architecture of communication system **10** can be logically broken into a cell site segment, a mobile telephone switching office (MTSO) segment, a regional sites segment, and a mobile data center (DC) segment.

A packet data network gateway (PGW)/serving gateway (PGW/SGW) **20** may be connected to Ethernet backhaul **18** and a data center through one or more intermediate network elements. The mobile data center may include a Multimedia Messaging Service (MMS) **24** and an Internet protocol (IP) Multimedia Subsystem (IMS) **26**. A Mobility Management Entity (MME) **28** is also provided for facilitating user interaction, such as tracking user equipment and authenticating users. Other networks, including an instantiation of the Internet, may be connected to the mobile wireless network at several locations, including at various network elements and Ethernet backhaul **18**.

Each of the elements of FIG. **1** may couple to one another through simple interfaces (as illustrated) or through any

other suitable connection (wired or wireless), which provides a viable pathway for network communications. Additionally, any one or more of these elements may be combined or removed from the architecture based on particular configuration needs. Communication system **10** may include transmission control protocol/Internet protocol (TCP/IP) communications for the transmission or reception of packets in a network, and may also operate in conjunction with a user datagram protocol/IP (UDP/IP) or any other suitable protocol where appropriate and based on particular needs.

Communication system **10** may be tied to the 3rd Generation Partnership Project (3GPP) Evolved Packet System architecture, but alternatively this depicted architecture may be equally applicable to other environments. In general terms, 3GPP defines the Evolved Packet System (EPS) as specified in TS 23.401, TS.23.402, TS 23.203, etc. The EPS consists of IP access networks and an Evolved Packet Core (EPC). Access networks may be 3GPP access networks, such a GERAN, UTRAN, and E-UTRAN, or they may be non-3GPP IP access networks such as digital subscriber line (DSL), Cable, WiMAX, code division multiple access (CDMA) **2000**, WiFi, or the Internet. Non-3GPP IP access networks can be divided into trusted and untrusted segments. Trusted IP access networks support mobility, policy, and AAA interfaces to the EPC, whereas untrusted networks do not. Instead, access from untrusted networks is done via the evolved PDG (ePDG), which provides for IPsec security associations to the user equipment over the untrusted IP access network. The ePDG (in turn) supports mobility, policy, and AAA interfaces to the EPC, similar to the trusted IP access networks.

Note that user equipment **12***a-c* can be associated with clients, customers, or end users wishing to initiate a communication in system **10** via some network. In one particular example, user equipment **12***a-c* reflects individuals capable of generating wireless network traffic. The term 'endpoint' is inclusive of devices used to initiate a communication, such as a computer, a personal digital assistant (PDA), a laptop or electronic notebook, a cellular telephone, an iPhone, a Blackberry, a smartphone, a tablet, an iPad, an IP phone, or any other device, component, element, equipment, or object capable of initiating voice, audio, video, media, or data exchanges within communication system **10**. User equipment **12***a-c* may also be inclusive of a suitable interface to the human user, such as a microphone, a display, or a keyboard or other terminal equipment. User equipment **12***a-c* may also be any device that seeks to initiate a communication on behalf of another entity or element, such as a program, a database, or any other component, device, element, or object capable of initiating an exchange within communication system **10**. Data, as used herein in this document, refers to any type of numeric, voice, video, media, or script data, or any type of source or object code, or any other suitable information in any appropriate format that may be communicated from one point to another.

For purposes of illustrating certain example techniques of communication system **10**, it is important to understand the communications that may be traversing the network. The following foundational information may be viewed as a basis from which the present disclosure may be properly explained. IP networks may provide users with connectivity to networked resources such as corporate servers, extranet partners, multimedia content, the Internet, and any other application envisioned within IP networks. While these networks generally function to carry data plane (user-generated) packets, they may also implicate control plane and management plane packets. Unlike legacy network technologies (e.g., Integrated Service Digital Network (ISDN), Frame Relay, and Asynchronous Transfer Mode (ATM)) that define separate data and control channels, IP networks carry packets within a single pipe. Thus, IP network elements such as routers and switches should generally be able to distinguish between data plane, control plane, and management plane packets, where this enables each packet to be suitably processed. In general, the data plane (also known as the forwarding plane or the user plane) provides the ability to forward data packets; the control plane provides the ability to route data correctly; the management plane provides the ability to manage network elements.

The vast majority of packets handled by a router travel through the router via the data plane. Data plane packets typically consist of end-station, user-generated packets that are forwarded by network devices to other end-station devices. Data plane packets may have a transit destination IP address, and they can be handled by normal, destination IP address-based forwarding processes. Service plane packets are a special case of data plane packets. Service plane packets are also user-generated packets that may be forwarded by network elements to other end-station devices, but they may require high-touch handling by a network element (above and beyond normal, destination IP address-based forwarding) to properly forward the packet. Examples of high-touch handling include such functions as Generic Routing Encapsulation (GRE) encapsulation, quality of service (QoS), Multiprotocol Label Switching (MPLS), virtual private networks (VPNs), and secure socket layer (SSL)/IPsec encryption/decryption. In a mobile network, the data plane may be responsible for packet processing at a session/flow level, multiple flows/session per active user, access control list (ACL)/traffic flow template (TFT) filters per user/flow, tunneling, rate limiting, subscriber scalability, security, and Layer 7 (L7) inspection. These activities are typically intensive in terms of memory and packet processing.

Control plane packets commonly include packets that are generated by a network element (e.g., a router or a switch), as well as packets received by the network that may be used for the creation and operation of the network itself. Control plane packets may have a receive destination IP address. Protocols that "glue" a network together, such as address resolution protocol (ARP), border gateway protocol (BGP), and open shortest path first (OSPF), often use control plane packets. In a mobile network, the control plane may be responsible for session management, call setup support requirements, interfacing with external servers (e.g., querying for per-user policy and control information), managing high availability for a gateway, and configuring and managing the data plane. Packet overloads on a router's control plane can inhibit the routing processes and, as a result, degrade network service levels and user productivity, as well as deny specific users or groups of users' service entirely.

Management plane packets also typically include packets that are generated or received by a network element. This may also include packets generated or received by a management station, which are used to manage a network. Management plane packets may also have a receive destination IP address. Examples of protocols that manage a device and/or a network, which may use management plane packets, include Telnet, Secure Shell (SSH), Trivial File Transfer Protocol (TFTP), Simple Network Management Protocol (SNMP), file transfer protocol (FTP), and Network Time Protocol (NTP).

Typically, mobile wireless service providers have selected and deployed gateway products that combine mobile wire-

less specific control plane functionality (and protocol usage) with data plane functions. The data plane functions may be used for classification, tunneling, feature enforcement, and accounting. Such a combined functionality may be viable for subscriber traffic models exhibiting low-data throughput and, further, having an active device population that supports data services in the few million range. However, as the number of subscribers and data throughput increases, this strategy can limit the ability of service providers to scale their systems accordingly. Service providers may also wish to focus on a smaller number of deployed platforms for both wireless and wireline networks in order to reduce the cost of day-to-day network operations.

In accordance with the teachings of the present disclosure, the architecture discussed herein offers a protocol for abstracting mobile wireless specific protocol usage and feature application from the data plane function. This can be used to provide content included on those protocol transactions or mobile wireless specific control-type functions. In general terms, the architecture can be configured to allow for the decomposition of the functionality and the characterization of the data plane to comport with familiar routing contexts.

More specifically, architecture of the present disclosure offers a protocol definition that abstracts the mobile wireless specific aspects from the data plane. This would be applicable to subscriber packets, as well as the mobile wireless specific usage of existing protocols. In specific implementations, the protocol can employ H.248 message constructs and, further, adopt the termination and context concepts of H.248. The architecture can add functionalities into those message constructs and, further, provide a single protocol for effectively processing network traffic.

Communication system **10** can offer mobility, policy control, authentication, authorization, and accounting (AAA) functions, and charging activities for various network elements. For example, interfaces can be used to exchange point of attachment, location, and access data for one or more end users. Resource, accounting, location, access network information, network address translation (NAT) control, etc. can be exchanged using a remote authentication dial in user service (RADIUS) protocol, a Diameter protocol, a service gateway interface (SGI), terminal access controller access-control system (TACACS), TACACS+, etc.

The architecture of communication system **10** could support a general-purpose router that is hosting the mobile wireless data plane function for a subscriber: without the need for mobile wireless specific knowledge at that router, or expertise for the operations staff tasked with managing that part of the network. The complexities of control plane interoperability, day-to-day management, policy, and billing system interaction can be efficiently concentrated in locations where specialist knowledge and suitable network infrastructure is available.

Semantically, three distinct functions can be used to achieve such an abstraction. First, there can be a discovery of nodes capable of supporting the specialized control plane functions, along with the discovery of other nodes capable of supporting the data plane functionality. Second, there can be a system-specific configuration to support additional internal configuration for supporting the separation. This could include available protocol proxies and application-specific configurations (e.g., access control lists (ACLs), pre-defined QoS and charging policies, pre-loaded deep packet inspection (DPI) policies, per-realm definitions, etc.). Third, there can be activities associated with session create, update, and delete being provided together with event notification. Semantically, the control plane can be divided into several segments in order to fully utilize available resources (e.g., within the chassis).

In operation, by using the defined protocol, the specialized control plane function would be responsible for parsing of the session create message, for interactions with the external policy server, and for abstracting elements pertinent to the data plane. These can be formulated in terms of parameters already familiar in the router technology environment (e.g., maximum bit rate, guaranteed bit rate, potential marking actions for conforming and exceeding traffic). These parameters can be sent to (and applied by) a network element (e.g., a router) that is configured to host the data plane for the subscriber.

Hence, the architecture of FIG. **1** is effectively reducing and eliminating the constraints of previous architectures by intelligently generalizing the data plane such that general-purpose routers can be leveraged. This can occur while concentrating specialized needs in a small number of more centralized control plane functions. Moreover, this data plane generalization further allows more user data to be offloaded at network elements much closer to the network edge (e.g., network element **16***a*). In one sense, the functions detailed herein can be distributed across the network in order to alleviate burdensome processing that would otherwise occur at a single network element. This would directly reduce the downstream processing requirements (e.g., at PGW/SGW **20**). The general-purpose processor could be a more robust processor, or have different performance metrics, or be more adept at processing certain types of information (e.g., video or voice), or be preferred (for other optimization reasons) over standard processors that exist in the network.

In operation, a message can be communicated to a remote data plane element (e.g., provisioned as software, provisioned as hardware, provisioned within a network element, provisioned at the edge of the network, etc.) in order to request a data plane resource (e.g., memory space, a processor allocation, bandwidth, etc.) for hosting a communication session. A response can then be received from the initiating network element acknowledging the message. The data plane traffic can be managed at the remote data plane based on enforcement rules, which can be reflective of any relevant policy, treatment, billing, protocol, etc. that may be applicable to this particular flow, to this particular user, to this particular tunnel, to this particular service provider, etc. The enforcement rules can be provisioned in a table element at the remote data plane element, where the table element reflects a portion of a master table element included in one of the network elements of a network. [Details associated with the table elements are provided below.]

Turning to FIG. **2**, FIG. **2** is a detailed block diagram illustrating potential logical components of PGW/SGW **20**. As shown, PGW/SGW **20** may be decomposed into SGW control plane (CP) functions **40**, SGW data plane (DP) functions **42**, PGW CP functions **44**, and PGW DP functions **46**. In general, there is significant functionality in the control plane with high transaction rates and memory requirements that would benefit from high-performance central processing units (CPUs). The data plane should be subscriber-aware and, with increasing radio access network (RAN) bandwidth, would benefit from high-performance packet processing. The data plane can be decomposed into four functions: classification, tunneling, enforcement, and accounting.

FIG. **3** is a simplified block diagram illustrating an example embodiment of a network element **50** (which could

be reflective of a PGW/SGW device, a router in the network, a gateway in the network, etc.). In this example, network element **50** is implemented in a single chassis, which may include a line card **52** and a mobility service module **54**. In network element **50**, data plane functions may be encoded in line card **52**, while control plane functions are embedded in mobility service module **54**. Mobility service module **54** also includes a DPI function and a CP-DP manager in this particular implementation. In certain implementations, an opaque packet transfer can occur (or any other mechanism) to divert specific flows from the data plane to a DPI capable network element, where the flows would then be sent back. Furthermore, there can be additional resources in the chassis with the line card (e.g., a service module) that can provide support for computationally intensive activities (e.g., L-7 classification in the chassis). These same computationally intensive activities might be supported via the opaque packet transfer at some point closer to the data center.

FIGS. **3** and **4** are somewhat related and, therefore, are discussed together. Note that the equipment of FIGS. **3** and **4** may be incorporated at any suitable location of communication system **10**. For example, the equipment of FIG. **3** and/or FIG. **4** could be deployed in the regional sites, the mobile telephone switching office, and/or the cell site (as being depicted in FIG. **1**). More specifically, FIG. **4** is a simplified block diagram of a network element **60** (which could similarly be reflective of a PGW/SGW device, a router, gateway, etc.). Network element **60** is representative of a distributed implementation, where control plane functions may be embedded in a server blade **62** of the network element. Data plane functions can be encoded on a separate network element in a different chassis (e.g., in a line card **64**). Line card **64** may be co-located on the same local area network, or geographically separated on a wide area network.

Note that the internal structure of network elements **50** and **60** may be similar in certain implementations of the present disclosure. For example, each network element **50** and **60** may include appropriate CP-DP managers, DPI elements, SGW DP and PGW DP instances, etc. In one particular configuration, network element **50** includes a processor **51**, a memory element **59**, and a set of master table elements **55***a-b*, where a portion (or a relevant slice) of master table elements **55***a-b* may be replicated in a set of table elements **57***a-b*. Similarly, network element **60** may include a processor **61**, a memory element **69**, and a set of master table elements **63***a-b*, where a portion (or a relevant slice) of master table elements **63***a-b* may be replicated in a set of table elements **65***a-b*.

In operation, the remote data plane is somewhat ignorant of the actual users and the actual (complete) policy sets that may be prevalent in the network. Instead, the remote data plane has a specific subset of enforcement rules to be applied. A given network element is configured to map a flow (out of a tunnel) against user-specific enforcement rules (inclusive of treatment rules). The mapping of the packets (out of the tunnel) to these user-specific rules (without having user data present or co-located at the network element) stands in contrast to existing architectures, which maintain a complete universe of all known policies and all known users. This creates significant, almost oppressive, levels of processing overhead. In one particular instance, an enforcement rule to be applied could be associated with a wireless mobility function.

The configurations of FIGS. **3-4** have the intelligence to use artifacts (i.e., any type of relevant data segments) from the tunnel in the mapping activity. The mapping can be provisioned in any suitable table (i.e., such as those illustrated in FIGS. **3-4**). In practical terms, though, the actual network element may be incapable of effectively maintaining the entirety of the master tables. In one particular instance, table elements **57***a-b* and table elements **65***a-b* include a portion of their respective master table elements, where that portion includes information associated with flows that are current for this particular network element, at this particular time, and involving a particular user.

To overcome the processing and storage challenges, the protocol of the present disclosure includes the incorporation of a smaller version of the master table element (e.g., replicated as a skinny table) at a lower level (e.g., at a line card level) of the network element. The skinny table essentially includes relevant data at this current time with regard to user-specific policies. That data could be suitably stored, cached, accessed, or otherwise provided by table elements **57***a-b* and table elements **65***a-b*. In one particular example, the control plane elements (e.g., SGW CP, PGW CP) dictate or otherwise control the portion of the master tables to be provisioned within the data plane elements. Note that the control plane understands which slices of rules (a minimal amount) are needed by the DP for making intelligent routing/policy decisions. Hence, it can be left up to the CP element to manage the appropriate rules such they are provisioned at the proper time to allow the DP element to execute its functions. In one sense, the DP element finds these rules as if it had the universe of all rules; however, the CP element is actually providing just-in-time information to the DP element for executing the appropriate function (e.g., a wireless mobility function). In one generic sense, the CP element has to systematically stay ahead of the DP such that the DP can timely perform its functions.

In one particular instance, network elements **50** and **60** are configured to exchange data in a network environment such that the mobile wireless functionality discussed herein can be achieved. As used herein in this Specification, the term 'network element' is meant to encompass various types of routers, switches, gateways, bridges, loadbalancers, firewalls, servers, inline service nodes, proxies, processors, modules, or any other suitable device, component, element, or object operable to exchange information in a network environment. The network element may include appropriate processors, memory elements, hardware and/or software to support (or otherwise execute) the activities associated with using a processor for mobile wireless functionalities in the data plane, as outlined herein. Moreover, the network element may include any suitable components, modules, interfaces, or objects that facilitate the operations thereof. This may be inclusive of appropriate algorithms and communication protocols that allow for the effective exchange of data or information.

In a specific implementation, network elements **50** and **60** include software to achieve (or to foster) the mobile wireless operations, as outlined herein in this document. For example, this could include mobility service module **54** and server blade **62**, which can be configured to execute many of the activities discussed herein with respect to mobile service functions. Furthermore, in one example, network elements **50** and **60** can have an internal structure (e.g., have a processor, a memory element, etc.) to facilitate some of the operations described herein. In other embodiments, all of these mobile wireless functions may be provided externally to this element, distributed in the network, or included in some other network element to achieve this intended functionality. Alternatively, any other network element can include this software (or reciprocating software) that can

coordinate with network elements **50** and **60** in order to achieve the operations, as outlined herein.

Note that in certain example implementations, the mobile wireless functions outlined herein may be implemented by logic (e.g., embedded logic provided in an application specific integrated circuit [ASIC], digital signal processor [DSP] instructions, software [potentially inclusive of object code and source code] to be executed by a processor, or other similar machine, etc.) encoded in one or more tangible media. In some of these instances, a memory element [as shown in FIGS. **3-4**] can store data used for the operations described herein. This includes the memory element being able to store software, logic, code, or processor instructions that are executed to carry out the activities described in this Specification. A processor can execute any type of instructions associated with the data to achieve the operations detailed herein in this Specification. In one example, the processor [as shown in FIGS. **3-4**] could transform an element or an article (e.g., data) from one state or thing to another state or thing. In another example, the activities outlined herein may be implemented with fixed logic or programmable logic (e.g., software/computer instructions executed by a processor) and the elements identified herein could be some type of a programmable processor, programmable digital logic (e.g., a field programmable gate array [FPGA], an erasable programmable read only memory (EPROM), an electrically erasable programmable ROM (EEPROM)) or an ASIC that includes digital logic, software, code, electronic instructions, or any suitable combination thereof.

Hence, any of the devices illustrated in the preceding FIGURES (e.g., the network elements of FIG. **1**) may include a processor that can execute software or an algorithm to perform the mobile wireless activities, as discussed in this Specification. Furthermore, network elements **50** and **60** can include memory elements for storing information to be used in achieving the intelligent mobile wireless operations, as outlined herein. These devices may further keep information in any suitable memory element [random access memory (RAM), ROM, EPROM, EEPROM, ASIC, etc.], software, hardware, or in any other suitable component, device, element, or object where appropriate and based on particular needs. Any of the memory items discussed herein (e.g., database, table, cache, key, etc.) should be construed as being encompassed within the broad term 'memory element.' Similarly, any of the potential processing elements, modules, and machines described in this Specification should be construed as being encompassed within the broad term 'processor.' Each network element **50** and **60** of FIGS. **3-4** can also include suitable interfaces for receiving, transmitting, and/or otherwise communicating data or information in a network environment.

Referring to FIG. **5**, FIG. **5** is simplified flow diagram illustrating example activities associated with communication system **10**. More specifically, the architecture is being depicted as abstracting certain mobile wireless specific aspects from the data plane. This would include both features that apply to subscriber packets, as well as the mobile wireless specific usage of existing protocols. In one embodiment of wireless network **10**, the protocol stack may be implemented with Ethernet and UDP at the transport layer. However, in an alternative embodiment, a Stream Control Transmission Protocol (SCTP) may be used at the transport layer, particularly in embodiments in which the control plane would be geographically separated from the data plane.

Above the transport layer, a robust inter-process communication mechanism can be employed (e.g., Transparent Inter-Process Communication (TIPC)), or any other appropriate mechanism. TIPC may be particularly advantageous because it is lightweight and, further, it provides location transparency of network services and a simplified addressing scheme (along with scalability and reliability). At the application layer, the protocol may use H.248 message constructs and adopt the termination and context concepts of H.248. However, the protocol may also add functionality within those message constructs and abstract specific protocol usage. Several distinct functions may be implemented for such an abstraction, which may be generally classified into six phases, as illustrated in FIG. **5**: 1) discovery; 2) configuration; 3) session establishment; 4) mid-session events; 5) session termination; and 6) opaque packet transfer.

Discovery is the process by which each protocol termination point within the physical data plane and control plane may discover available resources in the network. This would allow the control plane and data plane to establish and to maintain connectivity. Many aspects of the mobile data plane functionality may be preconfigured. These can cover two areas: functionality related to the mobility application itself and system configuration for the independent elements to function together. Part of this configuration may be manually preconfigured; the remainder may be automated at the control plane and occur as a result of configuration actions at the control plane. The application-specific configuration may support aspects such as interface definitions (e.g., physical interfaces, VLANs, addresses assigned to those interfaces), tunnel terminations (e.g., GTPv1, GTPv0, GRE, L2TP, IPinIP), per-access point name (APN) configurations, and policy for DPI, charging, policy and control. The system configuration may support aspects such as address assignment for service resources, pre-population for line card (LC) service switching to specific mobility service resources, configuration proxy, SNMP management proxy, Dynamic Host Configuration Protocol (DHCP) Server proxy, Layer 2 tunneling protocol (L2TP) control point, Gy proxy, Gz/Ga proxy, Syslog proxy, and service resource load reporting proxy, etc.

Referring to FIG. **6**, FIG. **6** is a simplified flow diagram **75** of a configuration that may be used in conjunction with communication system **10**. In this particular scenario, a configuration entity **70** may send a Config-Dataplane message **72** to a service resource blade **74** selected by configuration entity **70**. Service resource blade **74** may exchange configuration messages **76** with a line card **78**. Once the configuration is complete, service resource blade **74** may return a Config-Dataplane-Acknowledgement message **76**, in which success or failure of the configuration attempt may be indicated.

During session establishment, the subscriber-specific treatment for upstream and downstream traffic may be passed to a data plane resource that can host a subscriber on a PGW/SGW. This corresponds to the point when the primary session is established, regardless of whether that session is subscriber-initiated or network-initiated. The per-subscriber information to be transferred from the control plane may be a combination of information derived from local configuration at the control plane, control plane resource management for loadbalancing, GPRS Tunneling Protocol (GTP) control plane messaging, exchanges with external servers (DHCP, Radius, Policy, and Online Charging), etc. This data may be sent in a Session-Create message, for example. In one embodiment of communication system **10**, a specialized control plane function may parse the

Session-Create message, interact with the external policy server, and then abstract elements pertinent to the data plane. These elements may be formulated in terms of parameters already familiar to general routers, such as maximum bit rate, guaranteed bit rate, potential marking actions for conforming and exceeding traffic. These parameters may be sent to a router that hosts the data plane for the subscriber, where the parameters would be properly applied. The data plane response, which may be provided in a Session-Create-Acknowledgement message, generally contains a Service Resource ID, a Line Card Resource ID, Type-Length-Value (TLV)/Attribute-Value Pair (AVP) for transparently carrying a preformatted charging record from the data plane to the control plane (i.e. records created by the DPI function that should be transferred in a protocol by the control plane to an external server, for example), etc.

Mid-session events generally include any further events that occur after a primary session context has been established for a subscriber (e.g., other than primary session context termination). For example, these types of events can be triggered by handover, activation of a secondary context Packet Data Protocol (PDP), additional dedicated Evolved Packet System (EPS) bearers, termination of a secondary context (PDP), release of one or more dedicated EPS bearers, charging event triggers (e.g., volume or time-of-day), policy-originated triggers (e.g., usage monitoring control), legal intercept, mid-session traffic redirection, QoS parameter updates, service data flow identification, establishment, cessation, change of Radio Access Type (RAT), roaming, and others. The message sent from the control plane, such as a Session-Update message, may contain the same parameters as sent on session establishment (in addition to an indication of the event that resulted in the mid-session update). The message returned by the data plane, such as a Session-Update-Acknowledgement, may contain counters if the event charging is triggered. The data plane can also originate an update message when an event occurs (as provisioned on initial session establishment).

Session termination can include termination of the primary session context. At session termination, a subscriber is no longer assigned to a data plane physical entity or any associated service resources. This is the default EPS bearer for LTE (primary PDP context for the gateway GPRS support node (GGSN)). Session termination can be triggered by the user equipment, or the network. Network-initiated termination can be the result of operator actions or Policy Charging and Rules Function (PCRF) initiation, for example. The control plane may send a Session-Terminate message to end the last context for a subscriber. The data plane may respond with a Session-Terminate-Acknowledgement message. The Session-Termination message may contain counters reflecting the end-of-session status.

An example of mobile wireless specific abstraction would be the case of per-subscriber QoS policies. Traditionally, on receipt of a session create request a mobile wireless gateway would send a Diameter message to a policy server. This message may contain specific attribute-value pairs (AVPs) defined in 3GPP standards, as well as any vendor-proprietary AVPs specific to the application. The policy server would return policies in rules containing AVPs: again defined in a way specific to the mobile wireless application. These would be parsed and applied directly to the data plane.

Similarly, for accounting, various schemes can be applied per-subscriber and returned via mobile wireless policy interactions. In pragmatic terms, the data plane is interested in maintaining packet and byte counts, together with a trigger (either volume or time), where the counts would be reported. The packaging of counts (to suit the billing scheme) applied for the subscriber is not visible to the router hosting the data plane function. In addition to per-subscriber accounting, messages providing for special per-subscriber treatment, such as in-chassis L7 DPI or off-board DPI processing may be signaled from the CP to the DP.

FIG. **7** is a simplified block diagram illustrating a potential flow associated with an embodiment of a mobile wireless functionality according to the present disclosure. More particularly, FIG. **7** is representative of a potential sequence for processing packets originating from a mobile device **80** (i.e., reflective of a type of endpoint). Note that the application of per-flow enforcement features and per-transaction enforcement features may be dependent on configuration and policy. The data plane generally would not prevent both feature sets being applied.

Upstream packets from mobile device **80** can be received at the gateway (e.g., encapsulated within a tunnel). These tunneled packets may be fragmented prior to arrival at the gateway, and may be reassembled at **82**, as depicted. Tunneled packet reassembly should cater for both in-order and out-of-order receipt of fragments. The feature context for a packet can be determined once the tunnel header has been received. Packets may be decapsulated at **84**, as shown in FIG. **7**.

Tunnel types may include GTPv1, GRE with key, GTPv0, etc. Independent of the tunnel type, the field of interest is that field, which is used to determine the correct data plane feature context to apply to the packet. This could involve a tunnel endpoint identifier (TEID) for GTPv1, a GRE key for GRE with a key mechanism, a tunnel identifier (TID) for GTPv0), etc. In the case of GTPv1 and GRE with key, the receiving gateway may allocate the TEID or GRE key, respectively, to be used by the communicating gateway. For GTPv0, the TID may be allocated by the sending gateway. Any of these data segments (which can be gleaned from the tunnel) can be used in order to map a given flow to particular rules associated with network traffic.

The TEID, GRE key, or TID, as appropriate for the tunnel type, can identify a specific EPS bearer or PDP context associated with the subscriber packet. The field can be unique for a given tunnel header source and destination IP pair. This may be used to determine the feature context for the packet: together with an identification of the EPS bearer or PDP context for that packet, as shown at **86**. Further classification of the packet may depend on the feature context. Service Data Flow (SDF) may be further classified at **88**, based on packet filters in per-user rules, which may be received from a policy server and, further, be maintained in the feature context. Per-flow classification and per-transaction classification may be applied based on policy and local configuration.

The set of features to be enforced for a given packet may be contained in the feature context. Three categories of such features may include: (1) features identified following classification to a bearer; (2) features identified as a result of further classification to a Service Data Flow; and (3) features identified as a result of further transaction-based classification. The feature context may be constructed from multiple sources such as through local configuration, per-gateway, and per-user: either manually configured or pre-loaded from a policy server. Another source could relate to per-user policy rules, which are sent from a policy server on session establishment or during an update. In other implementations, the source could include a derived per-transaction context for L7 Heuristic and Transaction classification.

At **90**, features may be enforced per-bearer, or alternatively at **92**, features may be enforced per a flow **95**. Packets may subsequently be reordered and reassembled (as needed) for TCP and UDP transactions at **94**. The DPI-CPAC classification (as shown at **96**) may be based on a configured interpretation of the port. At **98**, additional enforcement per DPI-CPAC may be applied. Packets may then be sent over network **100** to its intended destination.

FIG. **8** is a simplified block diagram illustrating another potential flow associated with an embodiment of a mobile wireless functionality according to the present disclosure. More particularly, FIG. **8** is representative of a potential sequence for processing packets originating from network **100**. At **102**, fragment reassembly may be necessary to correctly decapsulate a tunneled packet. Tunnel encapsulation may be supported at **104** for enterprise tunneling. Classification of the user packet at **106***a* and **106***b* may be provided at three levels: (1) per-transaction, (2) per-flow, and (3) per-bearer/PDP context. Classification for downstream traffic may first identify the subscriber context together with the information necessary to perform per-bearer classification. Additionally, an evaluation can be made as to whether per-transaction or per-flow classification is required in addition to the per-bearer classification. Then, if indicated by context, a per-transaction or per-flow classification may be applied together with the associated features. This is followed by application of appropriate per-bearer features.

At **108**, features may be enforced per-flow; at **110**, features may be enforced per-bearer. Packets may be reordered and reassembled as needed for TCP and UDP transactions at **112**. DPI-CPAC classification at **114** may be based on a content rule and policy map rule match. At **116**, additional enforcement per DPI-CPAC may be applied. Packets may then be sent to mobile device **80**. Opaque packet transfer may be needed to handle packets during certain operations, including mobile/DHCP server interactions for address assignment, L2TP tunnel control signaling, diversion of GTP signaling messaging, and legal intercept.

A mobile device may be permitted to request dynamic address assignment for a session by using DHCP procedures. DHCP message interchange may be transferred between the mobile device and the gateway as user plane traffic within a GTP tunnel for the appropriate EPS bearer/PDP context. The DHCP server interface may be hosted in the control plane. For the mobile-to-DHCP server direction, the data plane may intercept DHCP packets from the mobile device. These DHCP packets can be destined for the IP address of the control plane, acting as a DHCP proxy for the mobile device. Note that whether the control plane requests an address from a DHCP server function integral with the control plane, or from an external DHCP address server, need not be visible to the mobile device.

Gateway-to-enterprise tunnel control signaling exchanges are generally necessary to establish an L2TP tunnel between the gateway acting as an L2TP access concentrator (LAC) and the enterprise functioning as a L2TP network server (LNS). The gateway address for the control messaging is the same as that being used for the L2TP tunnel itself. For the gateway-to-enterprise direction, the tunnel establishment messages may be originated from the control plane. The source UDP port of the tunnel establishment message may be populated to uniquely identify the control plane. For the enterprise-to-gateway direction, the L2TP signaling messages may be received at the data plane. The destination UDP port of the signaling message is that from the corresponding received signaling message. Based on this port, the received message may be sent from the data plane to the control plane using opaque transfer in certain implementations of the present disclosure.

For GTPv0 and GTPv1, the IP address for control plane signaling is generally the same as that for the GTP tunnel termination. For GTPv2, the address may be different, or it could be the same. Independent of the version, GTP control plane messages received at the gateway may be transferred to the control plane using an opaque transfer operation. For GTPv2 and v1, the destination UDP port for control plane messaging may be used to identify those messages, as the port is different from that defined for the data plane GTP tunnel. For GTPv0, the same destination port may be used for both control and data plane packets and, thus, GTPv0 data packets may be identified by a GTP message type of 255. For legal intercept, packets corresponding to a mobile device may be duplicated and sent to a remote device. The format for encapsulating packets can be 3GPP-specific, or provided in any other suitable format. In order to remove certain processing burdens from the data plane, duplicated packets may be sent to the control plane for transfer to the remote device. These packets may be transferred using the opaque transfer operation.

Note that there are other alternative arrangements of communication system **10**, which can be similarly deployed in order to achieve the teachings of the present disclosure. For example, in order to fully utilize the general-purpose routers discussed herein (for the data plane function of a mobile wireless gateway), the interfaces specific to mobile wireless can be offloaded to a protocol proxy function. The protocol proxy can be configured to implement the mobile wireless specific usage of protocol, formatting of information elements, transmission mechanisms of wireless-standards specific interfaces, etc. This would not necessarily be extended to the content that is being transferred in those protocols.

A protocol supporting the interaction between the generic data plane and the mobile wireless specific control plane can incorporate information identifying the protocol proxy to be used for a given subscriber session, for each of the mobile wireless specific interfaces. Additionally, the protocol proxy could be identified by direct address (e.g., the IP address plus a suitable identifier), or by name to indicate one of a pre-configured set of proxies known at the data plane. The protocol proxy could be selected using any suitable mechanism (e.g., using round robin), where the selection could be made from the available proxies, perceived loading of the available proxies, nearest proxy based on perceived transmission latency, etc.

In operation, the data plane would be responsible for providing content to be encoded in a mobile wireless specific protocol. The data plane would also be responsible for understanding content received via a mobile wireless specific protocol, but necessarily not the implementation of the protocol itself. Additionally, the focus on the protocol proxy function removes the need for a mobile wireless specific protocol functionality in the general-purpose router. This may be achieved with the understanding that a suitable general-purpose CP/DP protocol is specified. Additionally, the architecture can include an intelligent selection of a proposed proxy based on any number of criteria. The protocol proxy may be provisioned in any suitable network element discussed herein in this Specification. For example, the protocol proxy may be provided in a router, a switch, a gateway, or any other network element: some of which are illustrated in the previously discussed FIGURES. The protocol proxy may be provisioned as hardware, software, or

any suitable combination of these elements. Furthermore, the protocol proxy may be a proprietary device, which can suitably communicate with any network element. The protocol proxy may be distributed at edges of the network in order to alleviate certain processing responsibilities of those network elements downstream of the protocol proxy.

Note that existing solutions embed the implementation of mobile wireless specific protocol usage in the product supporting the mobile wireless gateway data plane. In contrast, the architecture of the present disclosure can be configured to remove the need to do that and, further, shift the proxy to a specialized function. This could allow a general-purpose router to support a single protocol rather than multiple mobile wireless specific protocol usages.

In accordance with one example implementation of the protocol proxy, the protocol used between the data plane function and the protocol proxy can be a single protocol, which would carry information such as User Identifiers, packet and byte counts, fields that would be inserted in charging records or policy responses such as transaction headers, time of connection, information that is generally of use to the backend systems, etc. The protocol proxy could leverage the 'non protocol specific format of the user IDs, or counts . . . ', and package those into the wireless standards specific protocol format (e.g., within a Diameter AVP, a Radius VSA, a GTP' TLV, etc.). The protocol proxy can also be configured to maintain any protocol specific state, session IDs, etc., which may be utilized by the wireless standards-based interface. In certain instances, the information that is passed to the proxy is not a fast path stream, but rather parameters related to (for example) charging record generation or policy responses. It is dissimilar to Radius or Diameter Proxy as the protocol proxy (e.g., it is not a Diameter In: Diameter Out, Radius In: Radius Out function).

In essence, for a given subscriber, information relevant for charging and policy is provided from the data plane element to the protocol proxy element in the form of a generalized protocol. The destination address for the proxy function can be provided on user session establishment. It would be possible for the charging information of some subscriber flows to be sent to one proxy address, where it is formatted into a GTP' record and information for other flows is sent to a proxy for formatting into a record (e.g., suitable for Gy).

Semantically, the control plane can host the charging (e.g., GTP', Gy), policy (e.g., Gx), management (SNMP, command line interface (CLI)), mobile signaling (e.g., GTP, VPN signaling such as LT2P), Authentication, Authorization, Accounting (e.g., Radius interfaces), etc. The data plane can be responsible for forwarding traffic, applying ACLs, QoS functionality, gathering statistics, extracting transaction-related fields from the packet flows for inclusion in charging and reporting records.

Note that with the example flows provided above, as well as numerous other examples provided herein, interaction may be described in terms of two, three, or four network elements. However, this has been done for purposes of clarity and example only. In certain cases, it may be easier to describe one or more of the functionalities of a given set of flows by only referencing a limited number of network elements. It should be appreciated that communication system **10** (and its teachings) is readily scalable and further can accommodate a large number of components, as well as more complicated/sophisticated arrangements and configurations. Accordingly, the examples provided should not limit the scope or inhibit the broad teachings of communication system **10** as potentially applied to a myriad of other architectures.

It is also important to note that the steps in the preceding FIGURES are associated with only some of the possible signaling scenarios and patterns that may be executed by, or within, communication system **10**. Some of these steps may be deleted or removed where appropriate, or these steps may be modified or changed considerably without departing from the scope of the present disclosure. In addition, a number of these operations have been described as being executed concurrently with, or in parallel to, one or more additional operations. However, the timing of these operations may be altered considerably. The preceding operational flows have been offered for purposes of example and discussion. Substantial flexibility is provided by communication system **10** in that any suitable arrangements, chronologies, configurations, and timing mechanisms may be provided without departing from the teachings of the present disclosure.

Although the present disclosure has been described in detail with reference to particular arrangements and configurations, these example configurations and arrangements may be changed significantly without departing from the scope of the present disclosure. For example, although the present disclosure has been described with reference to particular communication exchanges involving certain network access, formatting, and traffic protocols, communication system **10** may be applicable to other exchanges, routing protocols, or routed protocols in which packets (not necessarily the routing protocol/packets described) are exchanged in order to provide wireless data, connectivity parameters, access management, etc. Moreover, although communication system **10** has been illustrated with reference to particular elements and operations that facilitate the communication process, these elements and operations may be replaced by any suitable architecture or process that achieves the intended functionality of communication system **10**.

In a separate endeavor, communication system **10** may generally be configured or arranged to represent a 3G architecture applicable to universal mobile telecommunications system (UMTS), Long Term Evolution (LTE), and/or code division multiple access (CDMA) environments in accordance with a particular embodiment. However, these architectures are offered for purposes of example only and may alternatively be substituted with any suitable networking system or arrangement that provides a communicative platform for communication system **10**. In other examples, FIG. **1** could readily include a serving general packet radio service (GPRS) support node (SGSN) using a Gn/Gp interface (instead of S3/S4), a gateway GPRS support node (GGSN), any type of network access server (NAS), etc. and all of these elements could interface with an authentication, authorization, and accounting (AAA) server. Moreover, the present disclosure is equally applicable to other cellular, wireless and fixed technologies including Wi-Fi, WiMAX, Femto, DOCSIS, DSL, Ethernet, etc.

Numerous other changes, substitutions, variations, alterations, and modifications may be ascertained to one skilled in the art and it is intended that the present disclosure encompass all such changes, substitutions, variations, alterations, and modifications as falling within the scope of the appended claims. In order to assist the United States Patent and Trademark Office (USPTO) and, additionally, any readers of any patent issued on this application in interpreting the claims appended hereto, Applicant wishes to note that the Applicant: (a) does not intend any of the appended claims to invoke paragraph six (6) of 35 U.S.C. section 112 as it exists on the date of the filing hereof unless the words "means for" or "step for" are specifically used in the particular claims;

and (b) does not intend, by any statement in the specification, to limit this disclosure in any way that is not otherwise reflected in the appended claims.

What is claimed is:

1. A computer-implemented method to support mobile-aware protocol functionality via mobile-agnostic data plane and mobile-aware control plane functions for a session hosted for a mobile network subscriber, the computer-implemented method comprising:

communicating a message from a network element to a remote data plane element comprising a mobile-agnostic router, the mobile-agnostic router comprising a router that does not implement any protocol functionality that is mobile-aware, in order to request a data plane resource for hosting the session for the mobile network subscriber, wherein the remote data plane element is designated to host mobile-agnostic data plane functions for the mobile network subscriber, wherein the data plane resource comprises at least one of memory space and processor allocation, wherein at least one of the data plane functions is subscriber-specific and pertains to at least one of classification, tunneling, feature enforcement, and accounting;

discovering: (i) mobile-aware nodes capable of supporting mobile-aware control plane functions for the session and (ii) mobile-agnostic nodes capable of supporting the mobile-agnostic data plane functions for the session;

performing a system-specific internal configuration by operation of one or more computer processors to abstract mobile-aware protocol functionality away from the remote data plane element by providing a protocol supporting separation of and interaction between the mobile-agnostic data plane functions and the mobile-aware control plane functions, in order to permit the mobile-agnostic router to serve as the remote data plane element, thereby reducing a measure of hardware complexity of the remote data plane element relative to having a mobile-aware router serve as the remote data plane element, the mobile-aware router comprising a router that implements protocol functionality that is mobile-aware, wherein one or more mobile-aware interfaces are offloaded to a protocol proxy function executing on a protocol proxy selected from the discovered mobile-aware nodes based on at least one of proxy availability, proxy load, and proxy transmission latency; and

communicating one or more subsequent messages to the remote data plane element in response to one or more events;

wherein the network element comprises a control plane element for performing mobile-aware control plane functions for the session, including controlling which portion of a master table element is to be provisioned in a table element at a line card comprising a remote data plane element, wherein the table element at the remote data plane element includes only enough information for the mobile network subscriber for mapping flows that are current for the remote data plane element.

2. The computer-implemented method of claim **1**, wherein data plane traffic is managed at the remote data plane element based on enforcement rules, wherein the enforcement rules are provisioned in a the table element at the remote data plane element, wherein the table element reflects a portion of the master table element included in the network element.

3. The computer-implemented method of claim **1**, wherein the control plane functions performed by the control plane element for the session further include parsing a session create message, interacting with an external policy server, and abstracting elements pertinent to a data plane corresponding to the mobile-agnostic data plane functions.

4. The computer-implemented method of claim **1**, wherein the remote data plane element comprises a general purpose router for performing mobile-agnostic data plane functions for the session.

5. The computer-implemented method of claim **1**, wherein communicating one or more subsequent messages to the remote data plane element in response to one or more events comprises:

communicating a first one or more subsequent messages to the remote data plane element in order to update the session in response to a mid-session event; and

communicating a second one or more subsequent messages to the remote data plane element in order to terminate the session in response to a termination event.

6. The computer-implemented method of claim **1**, wherein the control plane element is divided into a first segment comprising packet data network gateway (PGW) functionality and a second segment comprising serving gateway (SGW) functionality in order to utilize resources within a chassis in which the remote data plane element resides;

wherein the PGW functionality comprises an interface between a mobile network and at least one other packet data network and the SGW functionality comprises an interface between a radio access node (RAN) of the mobile network and the PGW;

wherein the data plane functions pertain to per-subscriber classification, per-subscriber tunneling, per-subscriber feature enforcement, and per-subscriber accounting;

wherein data plane traffic is managed at the remote data plane element based on enforcement rules, wherein the enforcement rules are provisioned in a the table element at the remote data plane element, wherein the table element reflects a portion of the master table element included in the network element;

wherein the control plane functions performed by the control plane element for the session further include parsing a session create message, interacting with an external policy server, and abstracting elements pertinent to a data plane corresponding to the data plane functions.

7. The computer-implemented method of claim **6**, wherein communicating one or more subsequent messages to the remote data plane element in response to one or more events comprises:

communicating a first one or more subsequent messages to the remote data plane element in order to update the session in response to a mid-session event; and

communicating a second one or more subsequent messages to the remote data plane element in order to terminate the session in response to a termination event.

8. The computer-implemented method of claim **7**, wherein the remote data plane element comprises a general purpose router for performing data plane functions for the session, wherein the control plane element is configured to be used for session management and call setup support activities associated with the session, wherein the computer-implemented method further comprises receiving a response at the network element acknowledging the message, wherein

at least one of the enforcement rules relates to a wireless mobility feature for the session, wherein a flow is mapped out of a tunnel against user-specific enforcement rules associated with the session.

9. The computer-implemented method of claim **8**, wherein one or more data segments from the tunnel are used in order to map the flow to the user-specific enforcement rules, wherein additional resources are included in the chassis to support layer 7 (L7) classification operations in the chassis;

wherein the L7 classification operations are coordinated with a packet transfer activity occurring at a network location proximate to a data center, wherein certain flows are communicated from the remote data plan to a deep packet inspection (DPI) capable network element, wherein the certain flows are communicated back from the DPI capable network element.

10. The computer-implemented method of claim **1**, wherein the control plane element is divided into a first segment comprising packet data network gateway (PGW) functionality and a second segment comprising serving gateway (SGW) functionality in order to utilize resources within a chassis in which the remote data plane element resides.

11. The computer-implemented method of claim **10**, wherein the PGW functionality comprises an interface between a mobile network and at least one other packet data network and the SGW functionality comprises an interface between a radio access node (RAN) of the mobile network and the PGW.

12. One or more non-transitory tangible media that includes code executable to perform an operation to support mobile-aware protocol functionality via mobile-agnostic data plane and mobile-aware control plane functions for a session hosted for a mobile network subscriber, the operation comprising:

communicating a message from a network element to a remote data plane element comprising a mobile-agnostic router, the mobile-agnostic router comprising a router that does not implement any protocol functionality that is mobile-aware, in order to request a data plane resource for hosting the session for the mobile network subscriber, wherein the remote data plane element is designated to host mobile-agnostic data plane functions for the mobile network subscriber, wherein the data plane resource comprises at least one of memory space and processor allocation, wherein at least one of the data plane functions is subscriber-specific and pertains to at least one of classification, tunneling, feature enforcement, and accounting;

discovering: (i) mobile-aware nodes capable of supporting mobile-aware control plane functions for the session and (ii) mobile-agnostic nodes capable of supporting the mobile-agnostic data plane functions for the session;

performing a system-specific internal configuration by operation of one or more computer processors when executing the code and to abstract mobile-aware protocol functionality away from the remote data plane element by providing a protocol supporting separation of and interaction between the mobile-agnostic data plane functions and the mobile-aware control plane functions, in order to permit the mobile-agnostic router to serve as the remote data plane element, thereby reducing a measure of hardware complexity of the remote data plane element relative to having a mobile-aware router serve as the remote data plane element, the mobile-aware router comprising a router that implements protocol functionality that is mobile-aware, wherein one or more mobile-aware interfaces are offloaded to a protocol proxy function executing on a protocol proxy selected from the discovered mobile-aware nodes based on at least one of proxy availability, proxy load, and proxy transmission latency; and

communicating one or more subsequent messages to the remote data plane element in response to one or more events;

wherein the network element comprises a control plane element for performing mobile-aware control plane functions for the session, including controlling which portion of a master table element is to be provisioned in a table element at a line card comprising a remote data plane element, wherein the table element at the remote data plane element includes only enough information for the mobile network subscriber for mapping flows that are current for the remote data plane element.

13. The one or more non-transitory tangible media of claim **12**, wherein data plane traffic is managed at the remote data plane element based on enforcement rules, wherein the enforcement rules are provisioned in a the table element at the remote data plane element, wherein the table element reflects a portion of the master table element included in the network element.

14. The one or more non-transitory tangible media of claim **12**, wherein the control plane functions performed by the control plane element for the session further include parsing a session create message, interacting with an external policy server, and abstracting elements pertinent to a data plane corresponding to the mobile-agnostic data plane functions.

15. The one or more non-transitory tangible media of claim **12**, wherein the remote data plane element comprises a general purpose router for performing mobile-agnostic data plane functions for the session.

16. The one or more non-transitory tangible media of claim **12**, wherein communicating one or more subsequent messages to the remote data plane element in response to one or more events comprises further comprises:

communicating a first one or more subsequent messages to the remote data plane element in order to update the session in response to a mid-session event; and

communicating a second one or more subsequent messages to the remote data plane element in order to terminate the session in response to a termination event.

17. An apparatus to support mobile-aware protocol functionality via mobile-agnostic data plane and mobile-aware control plane functions for a session hosted for a mobile network subscriber, the apparatus comprising:

a memory element configured to store data;

a mobility module;

one or more computer processors operable to execute instructions associated with the data; and

a network sensor configured to interface with the memory element and the one or more computer processors, wherein the apparatus is configured to:

communicate a message from a network element to a remote data plane element comprising a mobile-agnostic router, the mobile-agnostic router comprising a router that does not implement any protocol functionality that is mobile-aware, in order to request a data plane resource for hosting the session for the mobile network subscriber, wherein the remote data plane element is designated to host mobile-agnostic data

plane functions for the mobile network subscriber, wherein the data plane resource comprises at least one of memory space and processor allocation, wherein at least one of the data plane functions is subscriber-specific and pertains to at least one of classification, tunneling, feature enforcement, and accounting;

discover: (i) mobile-aware nodes capable of supporting mobile-aware control plane functions for the session and (ii) mobile-agnostic nodes capable of supporting the mobile-agnostic data plane functions for the session;

perform a system-specific internal configuration to abstract mobile-aware protocol functionality away from the remote data plane element by providing a protocol supporting separation of and interaction between the mobile-agnostic data plane functions and the mobile-aware control plane functions, in order to permit the mobile-agnostic router to serve as the remote data plane element, thereby reducing a measure of hardware complexity of the remote data plane element relative to having a mobile-aware router serve as the remote data plane element, the mobile-aware router comprising a router that implements protocol functionality that is mobile-aware, wherein one or more mobile-aware interfaces are offloaded to a protocol proxy function executing on a protocol proxy selected from the discovered mobile-aware nodes based on at least one of proxy availability, proxy load, and proxy transmission latency; and

communicating one or more subsequent messages to the remote data plane element in response to one or more events;

wherein the network element comprises a control plane element for performing control plane functions for the session, including controlling which portion of a master table element is to be provisioned in a table element at a line card comprising a remote data plane element, wherein the table element at the remote data plane element includes only enough information for the mobile network subscriber for mapping flows that are current for the remote data plane element.

18. The apparatus of claim **17**, wherein data plane traffic is managed at the remote data plane element based on enforcement rules, wherein the enforcement rules are provisioned in a the table element at the remote data plane element, wherein the table element reflects a portion of the master table element included in the network element.

19. The apparatus of claim **17**, wherein the control plane functions performed by the control plane element for the session further include parsing a session create message, interacting with an external policy server, and abstracting elements pertinent to a data plane corresponding to the mobile-agnostic data plane functions.

20. The apparatus of claim **17**, wherein the remote data plane element comprises a general purpose router for performing mobile-agnostic data plane functions for the session.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 10,110,433 B2
APPLICATION NO. : 14/633572
DATED : October 23, 2018
INVENTOR(S) : Gary B. Mahaffey et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page

On the page 4, in Column 1, under "Other Publications", Line 32, delete "ieff." and insert -- ietf. --, therefor.

In the Specification

In Column 15, Line 47, delete "LT2P)," and insert -- L2TP), --, therefor.

In the Claims

In Column 17, Line 64, in Claim 2, delete "a the" and insert -- the --, therefor.

In Column 20, Line 23, in Claim 13, delete "a the" and insert -- the --, therefor.

In Column 22, Line 16, in Claim 18, delete "a the" and insert -- the --, therefor.

Signed and Sealed this
Ninth Day of April, 2019

Andrei Iancu

Andrei Iancu
Director of the United States Patent and Trademark Office